SECURITY INFORMATION

~~CONFIDENTIAL~~

c. 1

Copy 5
RM L52E07a

Unavailable
SEP 24 1952

NACA RM L52E07a

RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF THE AILERON EFFECTIVENESS OF THE REPUBLIC XF-91 AIRPLANE OVER A MACH NUMBER RANGE FROM 0.40 TO 0.91

By Thomas R. Sisk

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
September 11, 1952

~~CONFIDENTIAL~~

Unavailable

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF THE AILERON EFFECTIVENESS OF THE REPUBLIC XF-91 AIRPLANE OVER A MACH NUMBER RANGE FROM 0.40 TO 0.91

By Thomas R. Sisk

SUMMARY

Flight tests have been conducted on the Republic XF-91 airplane to investigate the aileron effectiveness at Mach numbers between 0.40 and 0.91 at approximate altitudes of 13,000, 24,000, and 32,000 feet. Abrupt rudder-fixed aileron rolls were made using from one-third to maximum aileron deflection.

The results obtained from these tests indicate that the aileron effectiveness is reduced by more than one-half as the Mach number increases from $M = 0.40$ to $M = 0.91$ at altitudes of about 13,000 feet. At the higher altitudes, the effectiveness at any Mach number is greater than the effectiveness at 13,000 feet. Over the range of dynamic pressures where comparable data were available, the aileron effectiveness decreases with increasing Mach number and the magnitude of this decrease is less at the higher values of dynamic pressure.

INTRODUCTION

The Republic XF-91 airplane is unconventional in that it has swept-back wings with inverse taper and variable incidence. It was felt that knowledge of the effects of these features on lateral stability and control of the airplane would be of general interest. For this reason the Republic Aviation Corp. has cooperated with the NACA High-Speed Flight Research Station in a flight investigation of the dynamic lateral stability and aileron effectiveness of the XF-91 airplane.

[redacted]

The present paper presents the aileron effectiveness data obtained during six flights of the airplane at Edwards Air Force Base, Calif. A summary of the aerodynamic characteristics and flying qualities, as obtained from rocket-propelled models, may be found in reference 1.

SYMBOLS

p	rolling angular velocity, radians/sec
r	yawing angular velocity, radians/sec
q	dynamic pressure, lb/sq ft
M	Mach number
V	true airspeed, ft/sec
h_p	pressure altitude, ft
b	wing span, ft
δ_a	aileron deflection (perpendicular to hinge line), deg
$pb/2V$	wing-tip helix angle, radians
i_w	wing incidence angle, deg
ϕ	angle of bank, deg

Subscripts:

L	left
R	right
T	total
max	maximum available deflection

AIRPLANE AND INSTRUMENTATION

The XF-91 airplane is a single-place, midwing monoplane powered by a General Electric J47-GE-17 turbojet engine. The wing is swept back 40°

at the 50-percent-chord line and has inverse taper and variable incidence. The physical characteristics of the airplane are listed in table I and a three-view drawing and photographs are presented in figures 1 and 2, respectively.

The ailerons are of the internal-sealed-balance type and have a maximum travel from 19° up to 16° down. The contour of the ailerons is specified as a continuation of the wing airfoil section. Details of the wing and the aileron cross section are shown in figure 3. The aileron controls employ a boost system which gives a maximum boost ratio of 40:1. The boost ratio used for the aileron effectiveness flights was approximately 10:1. Five of the six flights were made with 0° wing incidence whereas the remaining flight was made with a wing incidence of 2°.

Synchronized NACA instrumentation was installed to record the following quantities: rolling angular velocity, yawing angular velocity, left aileron position, and rudder position. Mach number, pressure altitude, and dynamic pressure were recorded on a photopanel.

It will be noted that only the left aileron was instrumented for these tests. The static difference between the left and right ailerons was measured and found to be zero within the accuracy of the calibration. Since no information was available on the effect of air loads on the aileron positions, the total aileron angle was taken as twice the left aileron angle.

TESTS, RESULTS, AND DISCUSSION

The results presented in this paper were obtained from abrupt rudder-fixed aileron rolls in the clean condition at various Mach numbers between 0.40 and 0.91. The rolls were made at approximate altitudes of 13,000, 24,000, and 32,000 feet, utilizing from one-third to maximum available aileron deflection. A chain stop was provided in the cockpit to enable the pilot to hold a constant control deflection until a constant rolling velocity was reached. Although rolls were made with incidence angles of 0° and 2°, the effect of changing wing incidence angle from 0° to 2° was found to be negligible.

Time histories of typical aileron rolls at various altitudes are presented in figure 4 for $M \approx 0.91$ and $M \approx 0.59$. Figures 5(a), (b), and (c) present the variation of wing-tip helix angle $pb/2V$ with total aileron deflection over the Mach number range covered at the three test altitudes. Figure 5 shows that there is a linear variation of $pb/2V$

with δ_a over the range tested. All rolls were made to the left with the exception of three that were made to the right at $M = 0.91$ at 23,200 feet (fig. 5(b)).

Figure 6 presents the variation of aileron effectiveness $\frac{pb/2V}{\delta_{a_T}}$ with Mach number at the three test altitudes. The data indicate that, at an altitude of about 13,000 feet, the aileron effectiveness decreases rapidly, more than 50 percent, from a value of 0.0025 at $M = 0.40$ to a value of 0.0010 at $M = 0.91$. At the higher altitudes, the effectiveness at any Mach number is greater than the effectiveness at 13,000 feet. The increase in effectiveness amounts to about 80 percent at $M = 0.91$ when the altitude is increased from about 13,000 feet to about 32,000 feet.

Figure 7 presents the variation of wing-tip helix angle $pb/2V$ with dynamic pressure for a total aileron angle of 20° at $M = 0.78$, 0.85, and 0.91. The data indicate that the aileron effectiveness decreases with increasing Mach number and the magnitude of this decrease is less at the higher values of dynamic pressure.

Time histories of the bank angles developed in the maneuvers of figure 4 were obtained by integrating the rolling velocity and are presented in figure 8. The rate of roll and aileron motion are also presented on this figure for convenience. The control deflections and the rolling maneuvers were not identical for the various altitudes and Mach numbers, so that sufficient data are not available to describe completely the change in angle of bank and time to obtain maximum rate of roll with altitude or Mach number. These data indicate, however, that the angle of bank at which maximum rolling velocity is obtained increases with altitude; for example, from about 70° for 13,600 feet to about 200° at 32,600 feet for $M = 0.91$. As pointed out in reference 2 rolling velocities developed at such large bank angles are of little use. The time required to obtain maximum rolling velocity was between 2 and 2.8 seconds whereas the time required to obtain 90° bank angle was between 1.6 and 2.4 seconds. These times are excessive when compared to the requirement of 1 second to bank 90° proposed in reference 2 and elsewhere.

CONCLUSIONS

From the aileron effectiveness tests on the Republic XF-91 airplane the following conclusions were drawn:

1. The aileron effectiveness was reduced by more than one-half as the Mach number increased from $M = 0.40$ to $M = 0.91$ at altitudes of about 13,000 feet. At the higher altitudes, the effectiveness at any Mach number is greater than the effectiveness at 13,000 feet.

2. Over the range of dynamic pressures where comparable data were available, the aileron effectiveness decreases with increasing Mach number and the magnitude of this decrease is less at the higher values of dynamic pressure.

3. The time required to obtain maximum rolling velocity was between 2 and 2.8 seconds whereas the time required to obtain 90° bank angle was between 1.6 and 2.4 seconds. The angle of bank at which maximum rolling velocity is obtained increased with altitude.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Mitcham, Grady L., and Blanchard, Willard S., Jr.: Summary of the Aerodynamic Characteristics and Flying Qualities Obtained From Flights of Rocket-Propelled Models of an Airplane Configuration Incorporating a Sweptback Inversely Tapered Wing at Transonic and Low-Supersonic Speeds. NACA RM L50G18a, 1950.

2. Williams, W. C., and Crossfield, A. S.: Handling Qualities of High-Speed Airplanes. NACA RM L52A08, 1952.

TABLE I.- PHYSICAL CHARACTERISTICS OF REPUBLIC XF-91 AIRPLANE

Wing:	
Airfoil section	Republic R-4, 40-1710-1.0
Area, sq ft	320.0
Span, ft	31.225
Aspect ratio	3.07
Taper ratio	1.626
Root chord (airplane center line), in.	95.0
Tip chord, in.	154.5
Mean aerodynamic chord, in.	127.1
Sweepback of 50-percent-chord line, deg	40.0
Geometric twist, deg	0
Cathedral, deg	5.0
Incidence angle, deg	Variable from -2 to 6
Slats (type)	
Leading edge	Full span
Flaps (type)	
Trailing edge	Plain partial span
Ailerons:	
Type	Internal sealed 30.2-percent balance
Area (one), sq ft	19.14
Span, in.	73.5
Sweepback angle of aileron hinge line, deg	42.5
Ratio aileron area to wing area affected	0.27
Travel, deg	-19 to 16
Vertical tail:	
Airfoil section	Republic R-4, 40-010X (Mod.)
Area, sq ft	48.4
Span, in.	117
Aspect ratio	1.99
Taper ratio	0.44
Sweepback at 25-percent-chord line, deg	33.0
Rudder area, sq ft	9.7
Horizontal tail:	
Airfoil section	Republic R-4, 40-010
Area, sq ft	69.8
Span, in.	204
Aspect ratio	3.98
Taper ratio	1.00
Sweepback at 25-percent-chord line, deg	40.0
Elevator area (total), sq ft	19.3
Elevator tab area, sq ft	1.03
Stabilizer area, sq ft	50.5
Fuselage:	
Length, ft	43.33
Frontal area (including canopy), sq ft	24.2
Fineness ratio (2 times length/maximum width plus height)	8.4
Canopy frontal area, sq ft	2.2
Power plant	1 General Electric J47-GE-17
Weight:	
Gross weight, lb	19,500
Empty weight, lb	15,900

NACA

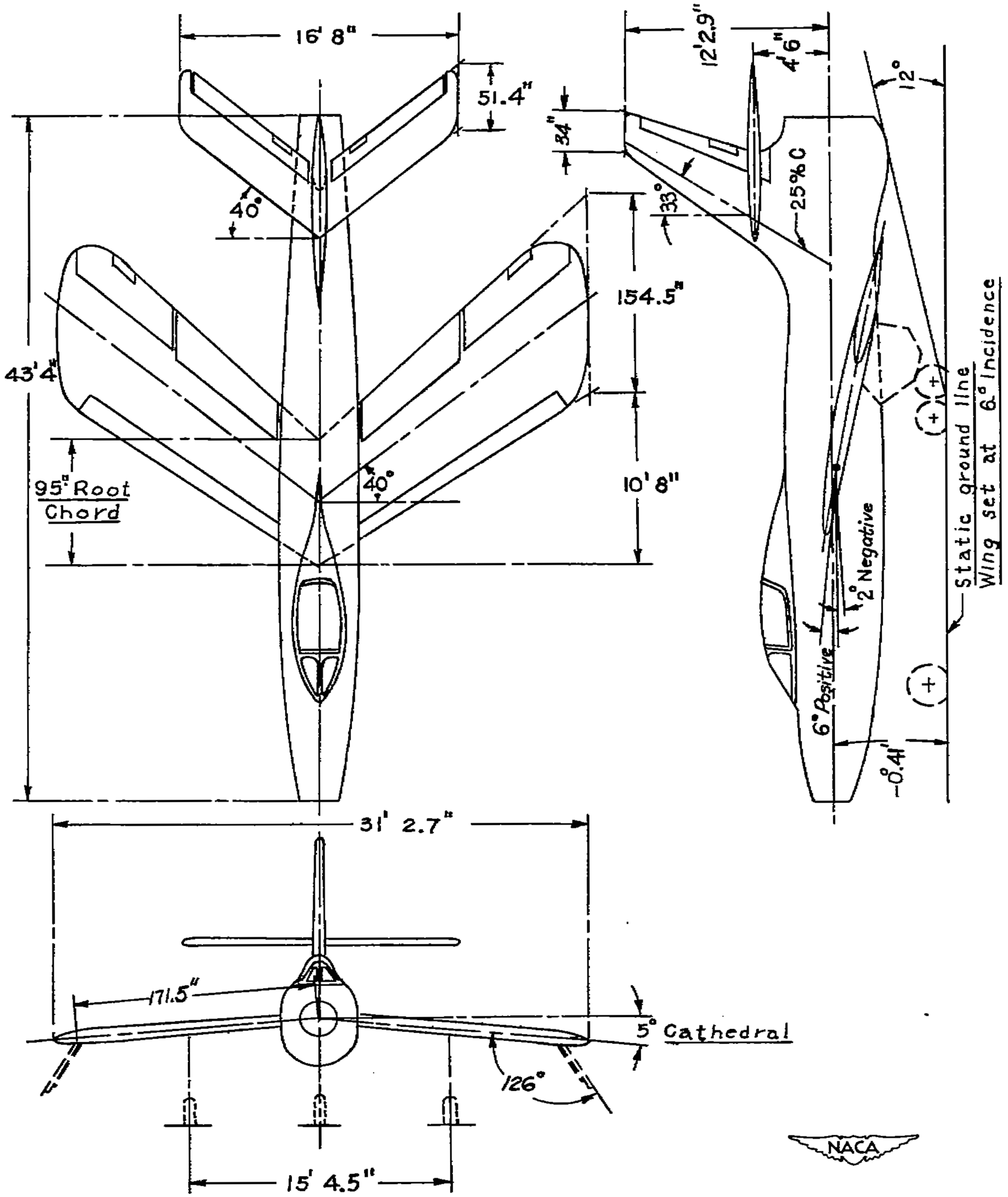
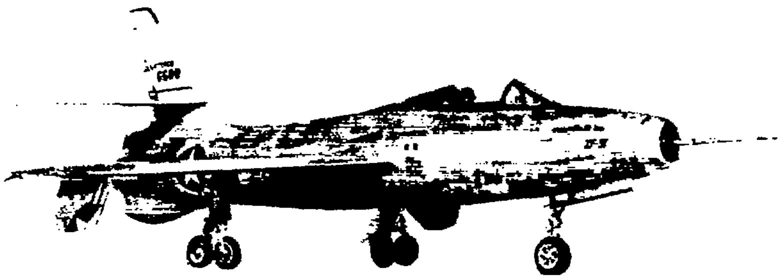
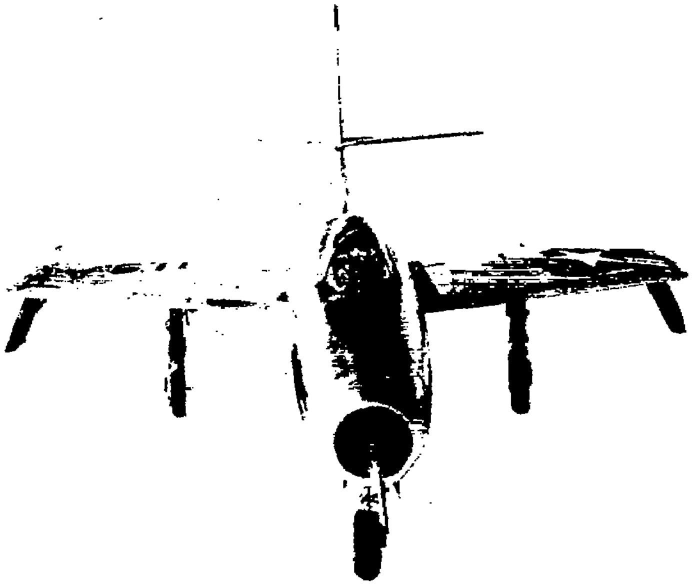


Figure 1.- Three-view drawing of the Republic XF-91 airplane.



(a) One-quarter front view.

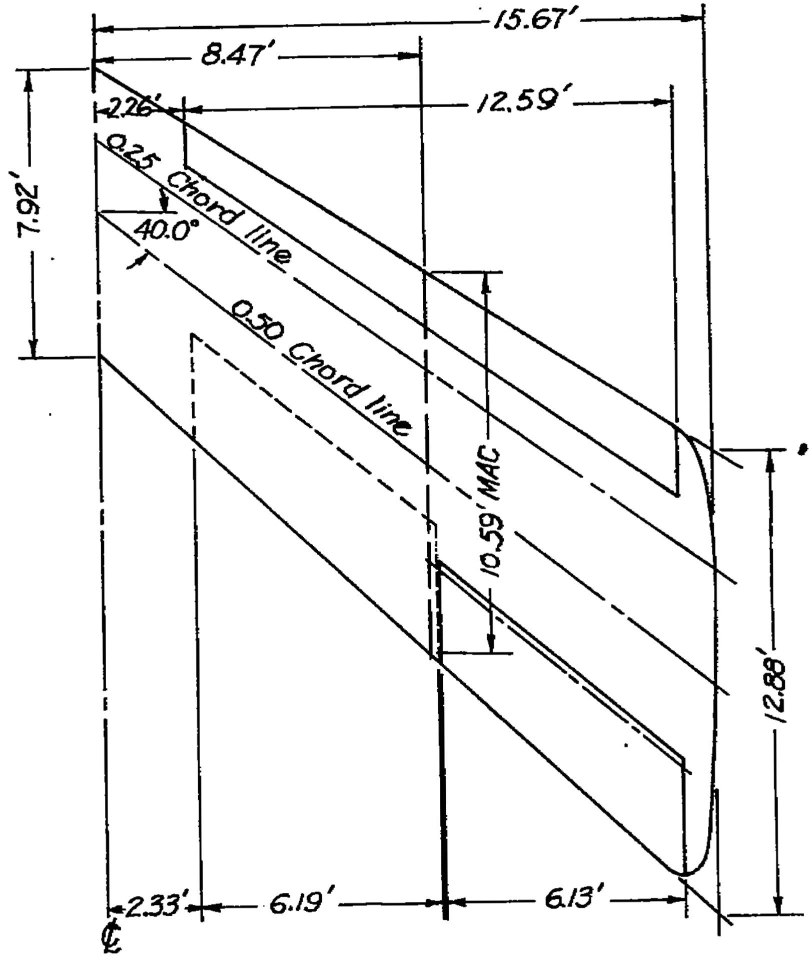
L-73281

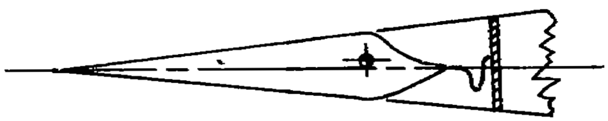


(b) Front view from above.

Figure 2.- Photographs of XF-91 airplane.

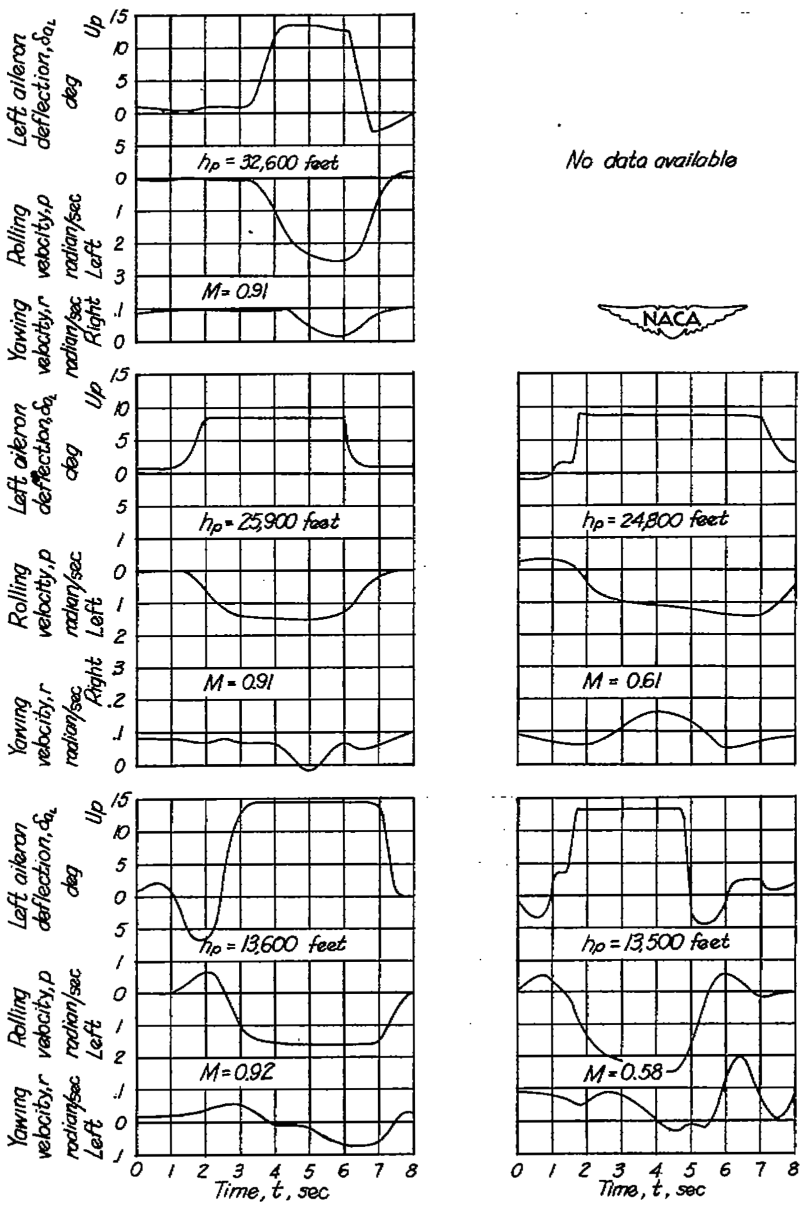
L-73280





Aileron cross section

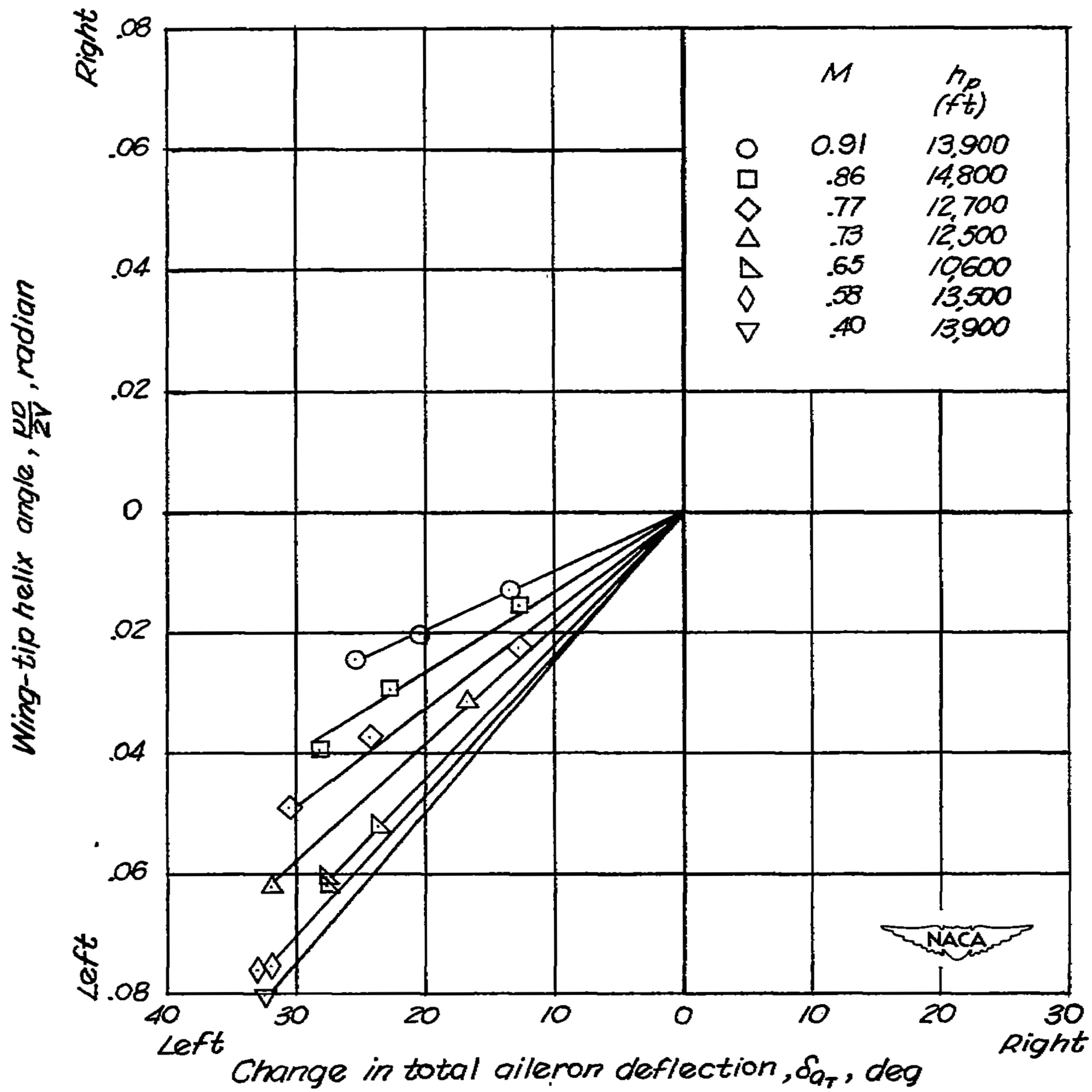
Figure 3.- Details of the XF-91 wing showing the aileron cross section.



(a) $M \approx 0.91$.

(b) $M \approx 0.59$.

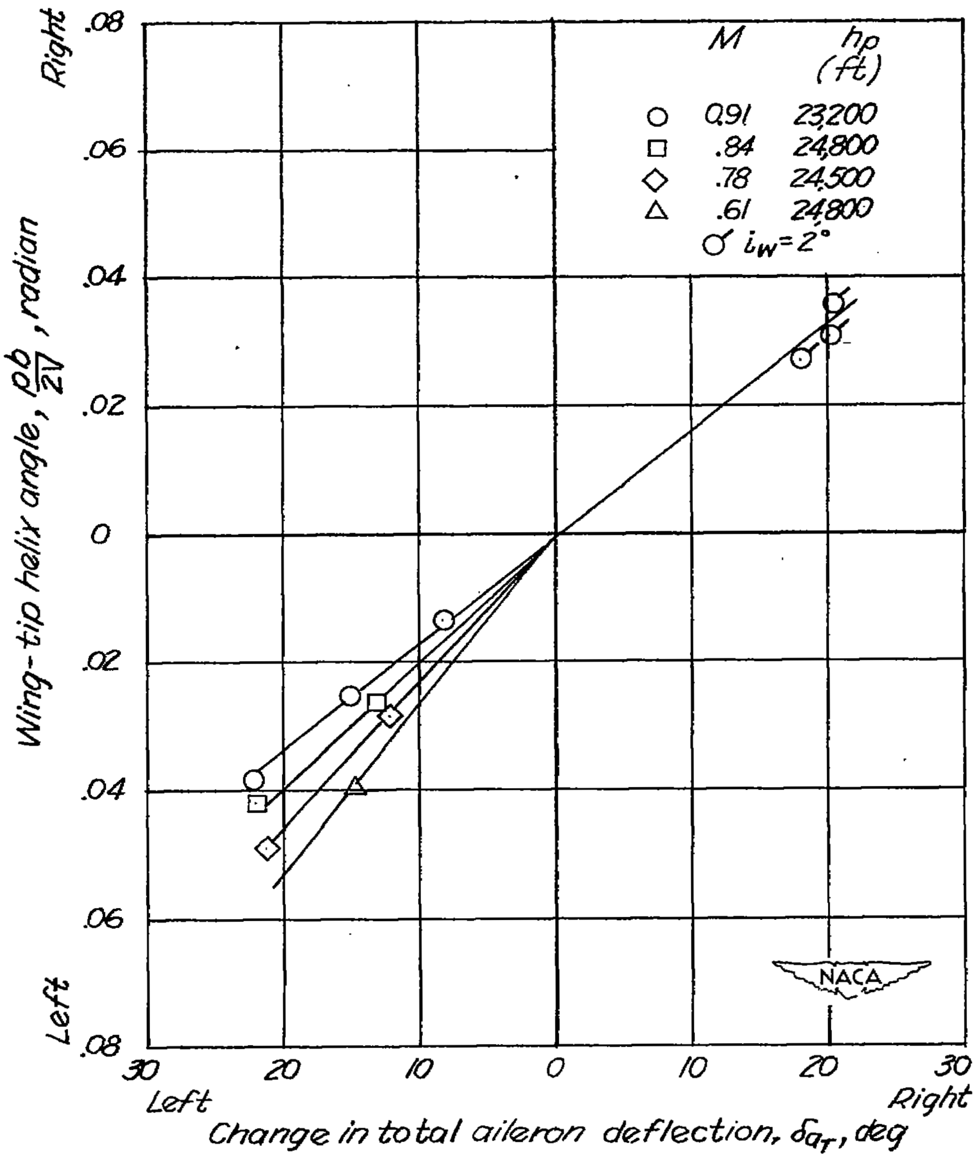
Figure 4.- Time histories of typical aileron rolls at $M \approx 0.91$ and $M \approx 0.59$ at various test altitudes. XF-91 airplane.



(a) h_p = 10,600 to 14,800 feet.

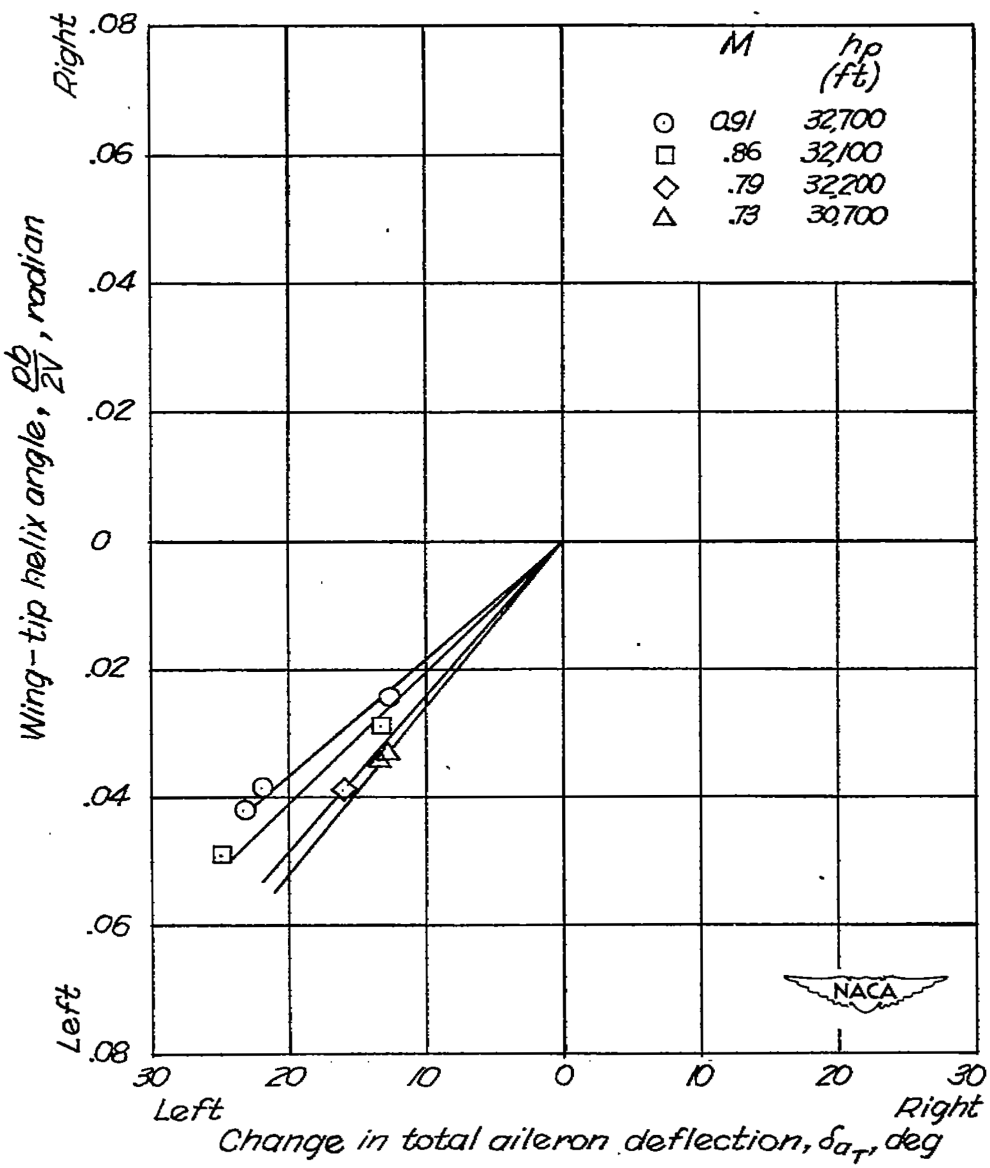
Figure 5.- Variation of wing-tip helix angle $\frac{pb}{2V}$ with total aileron angle as measured in abrupt aileron rolls; $i_w = 0^\circ$ except as noted. XF-91 airplane.

[redacted]



(b) h_p = 23,200 to 24,800 feet.

Figure 5.- Continued.



(c) h_p = 30,700 to 32,700 feet.

Figure 5.- Concluded.

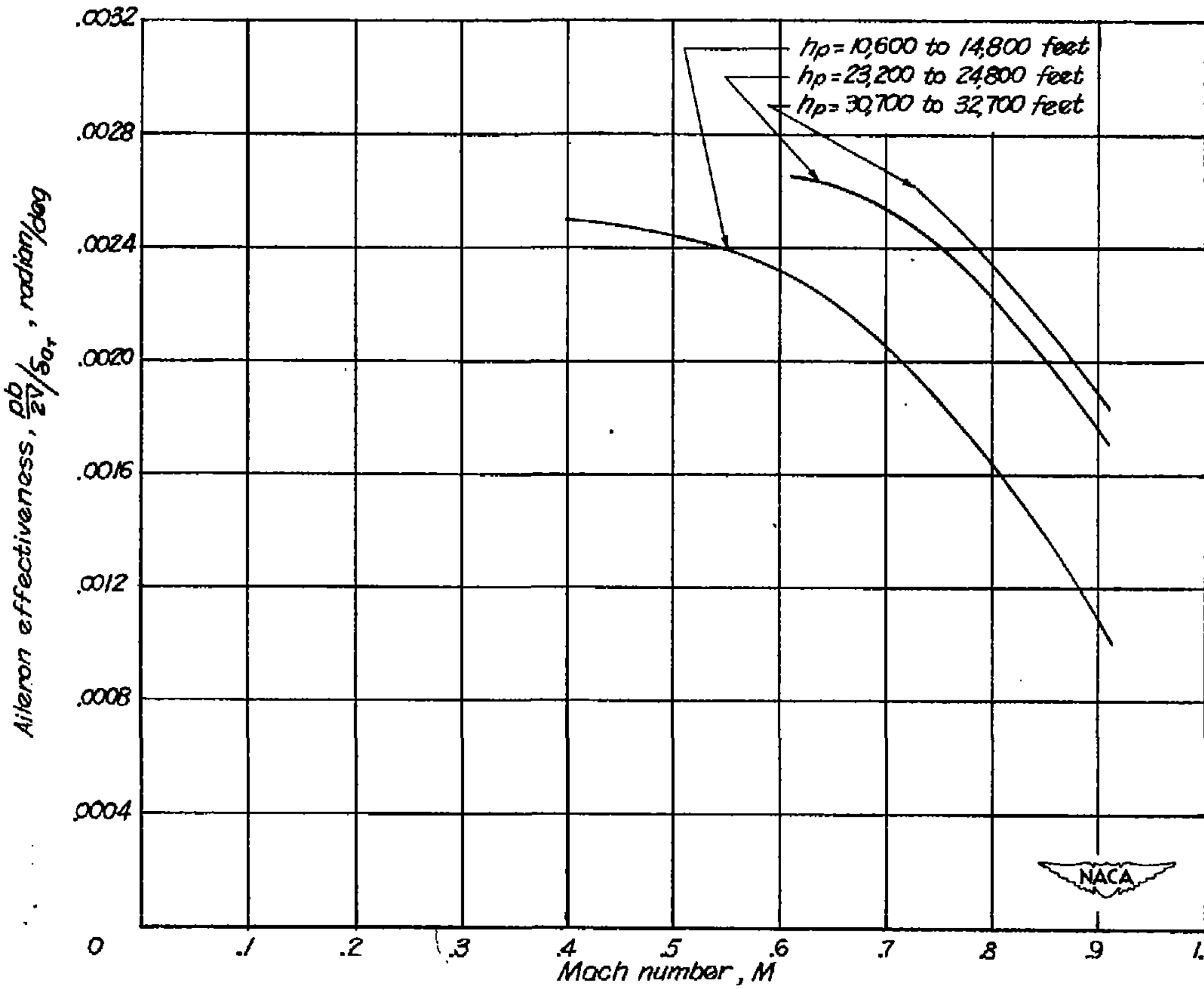


Figure 6.- Variation of aileron effectiveness with Mach number at three test altitudes. XF-91 airplane.

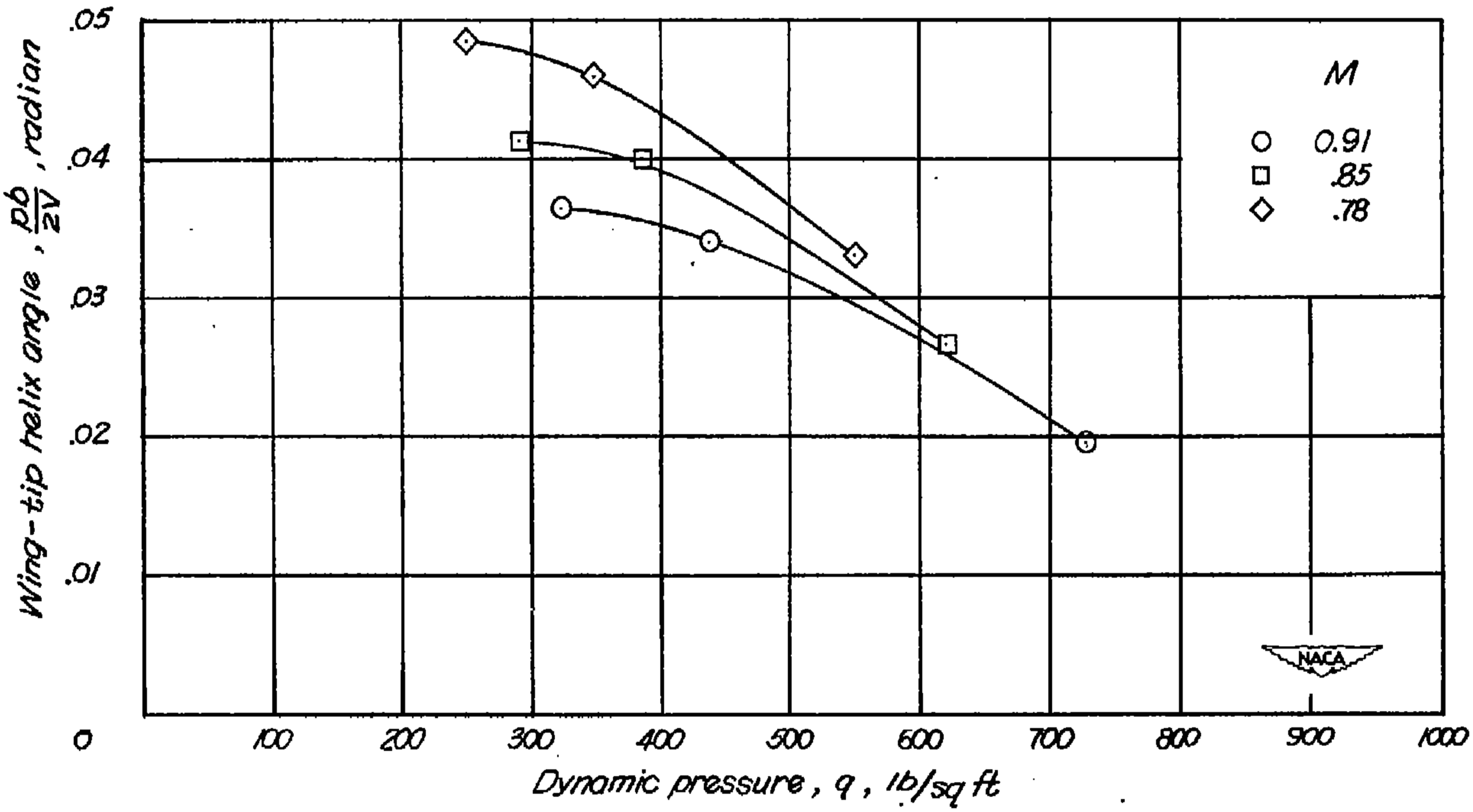
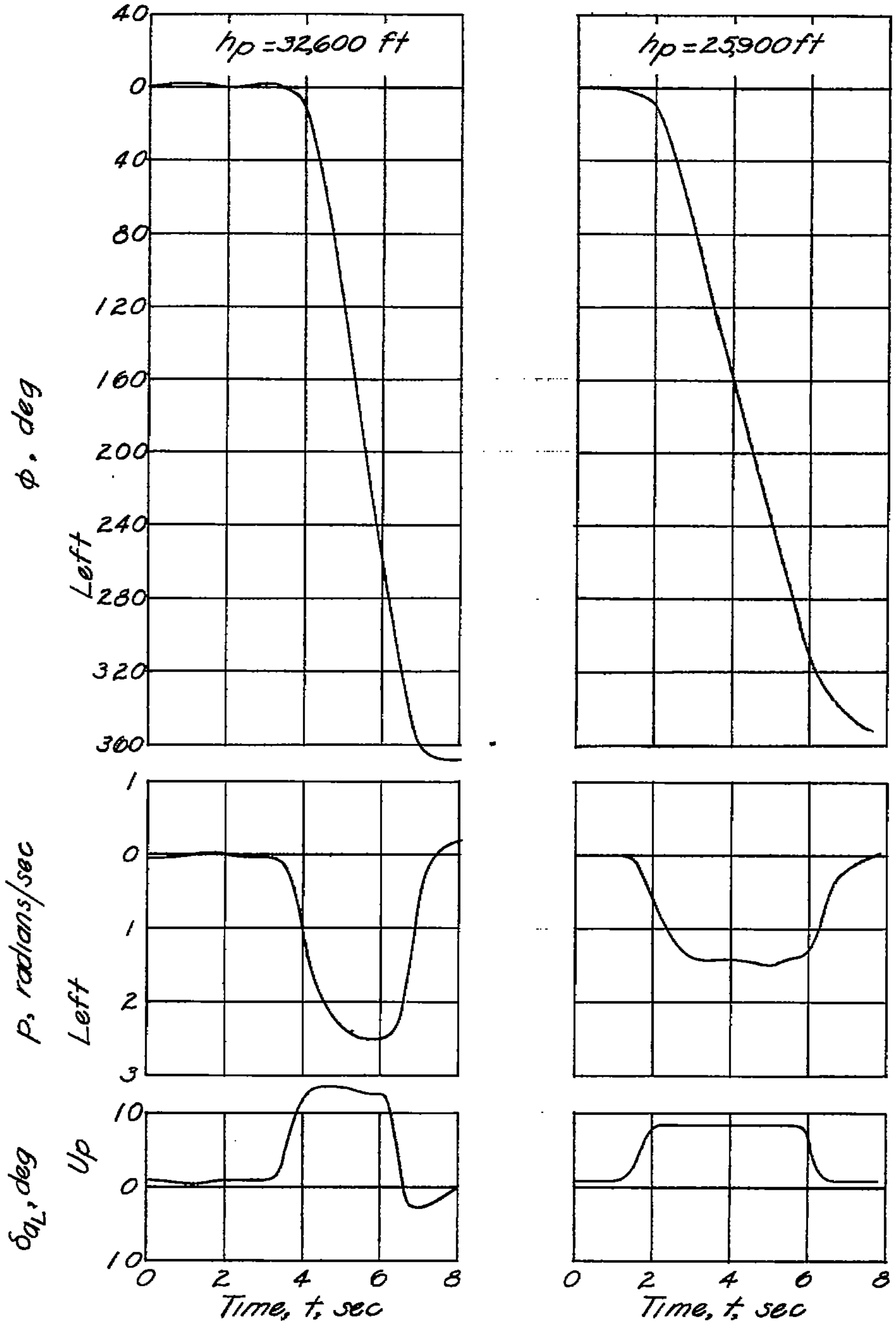


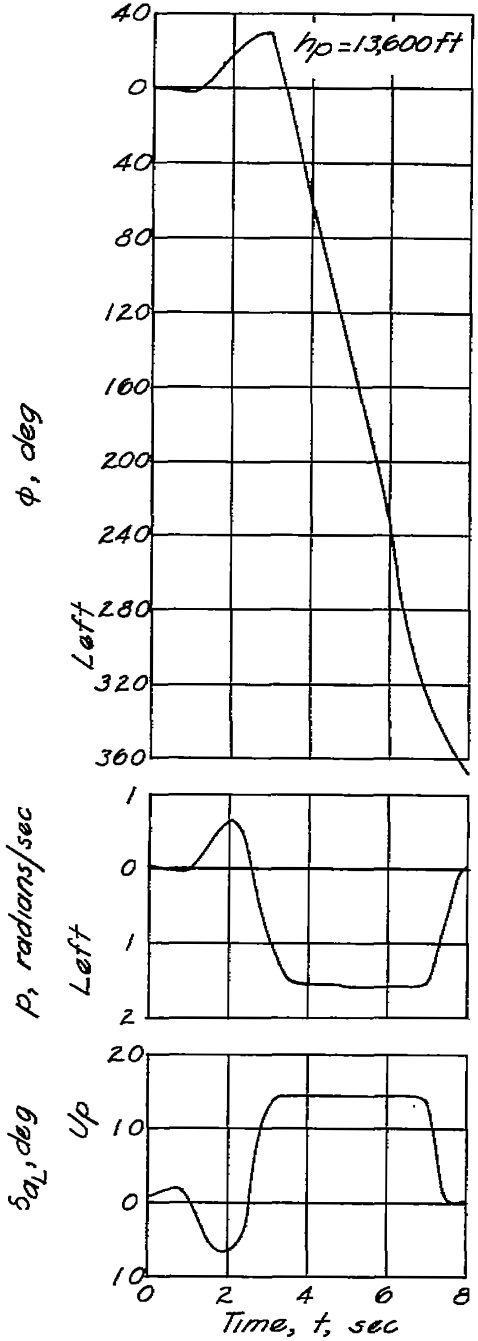
Figure 7.- Variation of wing-tip helix angle $\frac{pb}{2V}$ with dynamic pressure for a total aileron deflection of 20° at three Mach numbers. XF-91 airplane.



(a) M = 0.91.

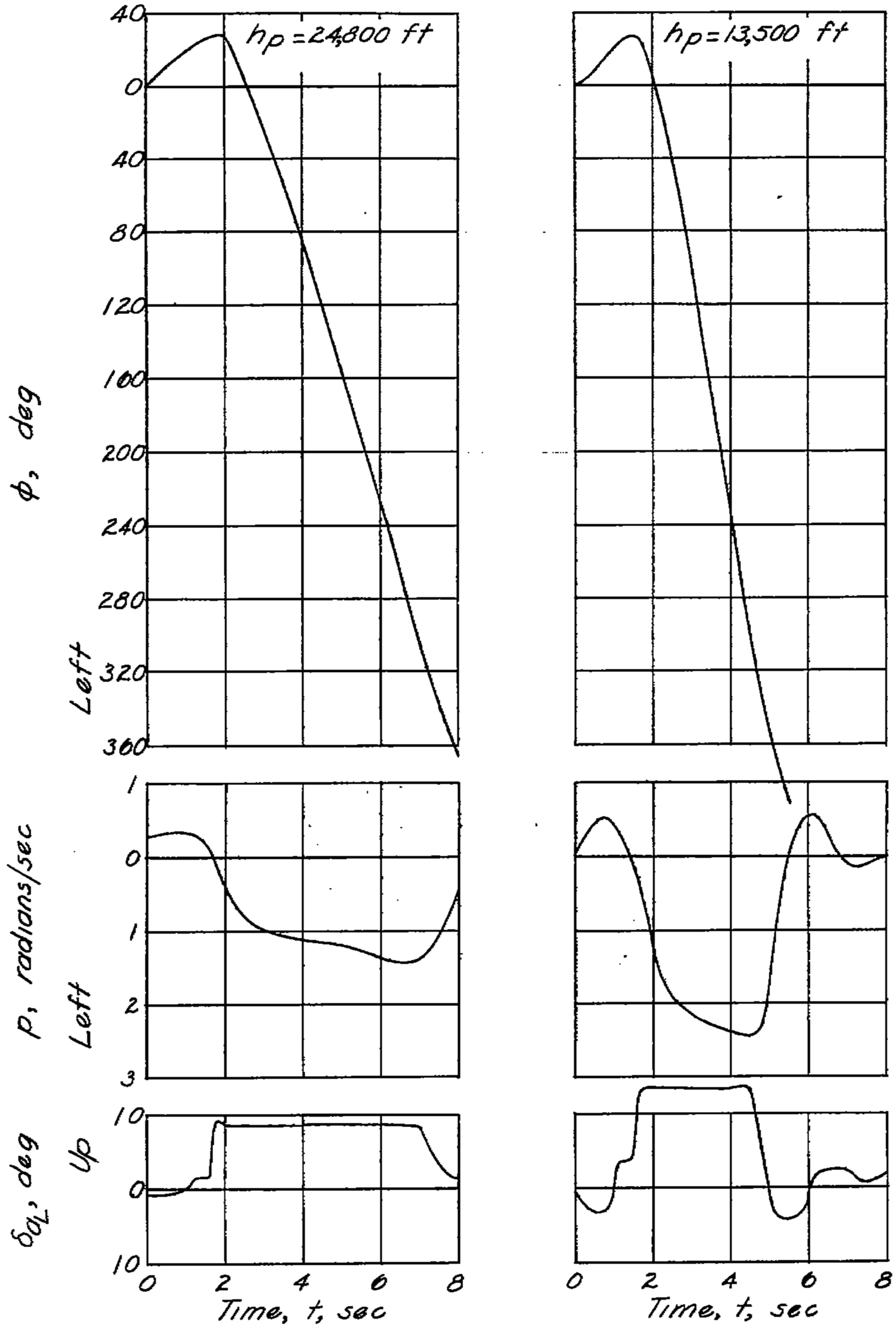
Figure 8.- Time histories of bank angles obtained during typical aileron rolls at M = 0.91 and M = 0.59 at various altitudes. XF-91 airplane.

[redacted]



(a) M = 0.91. Concluded.

Figure 8.- Continued.



(b) M = 0.59.

Figure 8.- Concluded.

NACA-Langley - 9-11-52 - 350

[redacted]